APPARATUS FOR LIQUID PURIFICATION

Description

This invention concerns apparatus for the purification of liquids. By purification is meant the removal of unwanted suspended, colloidal or dissolved substances from a liquid.
The prior art of apparatus to achieve this consists of a large variety of generically related filters that ulilize over-pressure and/or under pressure to provide the necessary pressure difference for filtration.
For the purification of liquids, filter presses or pressure leaf, candle and cartridge filters (pressure vessels containing such elements) are mainly utilized. Such liquids are chemicals, pharmaceutical products, beer, wine, sugar, oils and fats, petroleum products, etc. Their purification normally involves some form of "in-depth" filtration or purification process, whereby the liquid to be purified is either passed through or forms thereby a bed of particulate purification aid whereby the separation mechanism is mostly a combination of sieving-action and adsorption. The purification aids that are used include diatomaceous earth (kieselguhr), bleaching earth, ion-exchange resin, activated carbon, etc., all normally in powder form. The solid residues can rarely be regenerated and their disposal poses an acute environmental problem.
On the other hand, using apparatus of the nutsche-type filter in the form of open or closed containers, water is filtered by means of gravity or over-pressure on a large scale by means of thick, static beds of coarse granular material (e.g. sand). These beds are regenerated after filtration by backwashing techniques and reused. Although this method is suitable for the filtration of relatively clean surface and ground water, it is wholly unsatisfactory for the purification of industrial and domestic effluent. The reason is that the back-washing and regeneration techniques of prior art sand filters

- are inadequate for washing out most of the large variety of suspended solids contained in industrial liquid effluent

and

- produce excessive amounts of contaminated backwash liquid.

Added to this, the static nature of the beds is unsuited for the filtration of particulate matter, as large sections of the bed remain unused and the necessity for utilizing relatively coarse granular material comprising the beds for removing organic and inorganic contaminants in solution precludes on economic grounds the possibility of utilizing the extensive range of available adsorbents comprising such materials as activated carbon, anthracite, ion-exchange resin, bleaching earth, molecular sieves, etc. required for removing specific contaminants in the field of effluent and water purification.
The goal of this invention is to further develop the art and science of "in-depth" filtration utilizing beds of loose material for the purification of liquids such as processed by the

above named industries, whereby the beds are regenerated and reused more effectively than with prior art methods, resulting in a considerable reduction in the quantity of liquid and solid waste for disposal. Considering the present practice, in both the industrial and communal sector, of discharging effluent to the natural environment that is incompletely purified, the further goal is to provide these sectors with an effluent and water purification apparatus that will enable liquid effluent to be recycled and polluted water to be rendered suitable for domestic and industrial purposes.

It is proposed that the apparatus of the invention will be far more compact and versatile compared with the prior art in that it can be installed not only in large industrial and communal plants, but also in the medium to small size industrial sector. This will be achieved by utilizing specific through-puts 10-100 times those normally employed by prior art filters. Specific through-puts of 50-200 $m^3/m^2.h$ will be possible because the beds will be maintained in an "open" condition throughout the filtration and/or purification cycles.

A further goal of the invention is to provide the liquid purification apparatus of the invention with the means for automatically selecting and applying varying types and grades of filter media and modes of operation according to the nature, filtration characteristics and requirements of any type of liquid purification operation, whereby no further distinction will be made between effluent, water and process liquid purification. The ultimate aim of the invention is to reduce the number of purification steps presently required for process liquid purification, whereby waste generation will be reduced and the purification media regenerated and reused, thus enhancing the competitiveness of these industries and simultaneously relieving the present impact on the environment. The aim of the invention with industries presently using liquids in their production processes for such operations as plating, dyeing, washing, coating, pickling, quenching, etc. is to provide the means for continuous regeneration to avoid the necessity for dumping into the environment.

THE INVENTION

Fig.1 is a schematic flow-sheet of the apparatus of the invention that consists of a purifying filter plant 1, comprising essentially a lower stationary filtrate chamber 2 with a porous upper surface on which a section of an intermittently movable filter belt 4 is supported which in operation is stationary and sealed at the periphery by vertically movable dependent rim portions 3 of an upper contaminant container 5 fitted with a conically perforated feed distributor 27 extending over the entire upper horizontal section, a bed regeneration apparatus 6, a bed material storage/dosing vessel 7, a filter aid suspension tank 11, one or more adsorbent storage/dosing devices 8, a reservoir for liquid to be purified 10 and a residue filter 9.

Filter aid suspended in liquid in tank 11 is dosed into the vented container 5. While the pressure difference between the container 5 and the lower filtrate chamber 2 is raised, liquid to be purified in reservoir 10, which may be dosed with flocculating

substances such as polyelectrolytes, is pumped using means 22 from reservoir 10 into container 5. Simultaneously, suspensions of bed material recycled from regenerator 6 and activated powdered adsorbents are dosed using means 7/20 & 8/19 under pressure to a mixing section 27 of the delivery conduit 12 controlled by microprocessor 15 from input data from instrumentation 14 and 13 in the delivery conduit 12 and the filtrate conduit 16 respectively. The liquid quality and process parameters (concentration) controlled include turbidity, pH, hardness, chlorinated organics, mineral oil, heavy metals, phosphates, nitrates, etc. as well as variables such as pressure difference and through-put. Filtrate is recycled, if necessary by means of a suction/vacuum pump (28), through conduits 16 & 17 to reservoir 10 until the concentration of contaminants in the filtrate is reduced to a set level as measured at 13. Filtrate flow is switched to conduit 18 whence it is collected in a reservoir not shown. On either reaching a pre-set pressure differential across the bed or a pre-set upper level of contaminant concentration as measured by instrumentation 13, pump 22 and all dosing apparatus are shut down and external gas is fed through conduit 23 to container 5 whereby the residual liquid in the chamber and bed is removed, after which the dependent rim portions 3 of container 5 are raised and the bed is transported by the filter belt 4 and discharged into the bed regenerator 6. The dependent rim portions 3 are lowered onto a fresh section of belt and the cycle described above is repeated. The regenerator 6, in effect, removes adsorbate and entrapped particulate matter (ultrasonics, turbulence, diffusion, etc.) from the internal and external surfaces of the granular material, which may be an adsorbent itself, thereby regenerating, cleaning and restoring the desired activities to these surfaces. Clean liquid is introduced to 6 through conduit 24 and by means of hydraulic classification action the adsorbate and particulate matter are removed through conduit 25 to filter 9 to recover a solid waste. Depending on its nature, the recovered fluid is recycled to 10 or reprocessed. Not shown are the means for introducing and removing the bed regenerating and reactivating fluids to and from bed regenerator 6.

Fig.2 is a schematic representation of a partly sectioned elevation of media feeding mechanisms of the invention. Prior art filters have the disadvantage that a replacement of filter media involves lengthy shut-down periods and often excessive manual manipulation. A further goal, therefore, of the present invention is to provide the means for automatically and quickly fitting a large variety of prefabricated materials (e.g. menbranes, paper, carton, etc.) to fulfill the requirements of the liquid processing industries. Pressure cylinders 215, normally taking the form of hydraulic or pneumatic rams are provided for actuating the dependent rim portions 3 of the filter container 5 in the vertical direction for bed removal and container closure.

A plurality of rolls of filter media 209, 210 are provided for feeding sections onto the lower filtrate chamber 2. Drive rollers 220, 221 located on the surface of the media rolls and actuated by a brake/clutch mechanism 225 driven by the filter belt 217 through idle

rollers 207, feed lengths of filter band over guides 223 into the rollers 207 onto the surface of the moving filter belt 217. Belt sensor 218 shuts down the belt drive motor 216 and actuates the band slitting mechanism 208 after which the section of filter medium and the supporting filter belt are finally positioned in the container 5 and the depending rim portions of the container are lowered to seal the periphery of said sections. After filtration the used sections of filter medium are normally transported out of the container 1 for disposal.

Cassettes 212, located externally to the filter container 1, are designed to feed pre-cut, pre-fabricated sheets of various types of filter media such as membranes, paper, carton, etc. into the filter container for filtration. Individual sheets are taken from the top of spring-loaded bundles 223 by means of actuated rubberized rollers 213 and fed on guides 224 to synchronously driven feeder belts 214, whereby after positioning on the porous upper surface of the filtrate chamber 2, the dependent rim portions 3 of the container 5 are lowered to seal both the belt and the overlying section of filter medium. After the filtration operation the material is transported out of the container 1 for disposal.

Fig.3 is a sectioned drawing showing an improved method for ensuring that the dependent rims 3 when they take the form of peripheral, integral sides of the container 5 are actuated in the horizontal orientation when raised and lowered and that the full thrust of the fluid driven pistons in cylinders 215 is exerted when sealing the container 5 against the horizontal pervious base 2. The bodies of the cylinders 305 are fixed to an external load-bearing framework 306 with the external extremity of the lubricated shafts 307 connected to the lower ends of vertically sectioned cylindrical sleeves 301 extending and fixed at the top end to transverse beams 308 that in turn actuate thrust shafts 303 acting directly through seals onto the top peripheral part of the container 5. Annular sections of guiding plastic material 302, preferably out of polytetrafluorethylene, are fixed to the surface of the cylinders fitting into the space between the surface of the cylinders and the inner surface of the reciprocating sleeves 302.

Fig.4 is a schematic representation of apparatus of the invention for:
- automatic selection of filter media;
- automatic selection of the optimal mode of filtration or purification;
- automatic measurement of the permeability of sections of filter media;
- automatic regeneration of partially 'blinded' sections of filter media.

A typical procedure according to the invention for the filtration or purification of a quantity of liquid of unknown filtration characteristics is the following:
A liquid is to be clarified, whereby the filtrate in the filter residue (cake) is to be

recovered by a washing operation. The required degree of clarification in units of turbidity is known. This and other pertinent information are entered into the programmed microprocessor 15 and the following sequence of operations proceeds fully automatically:
Start:

1. A section of 10 micron retention filter paper from 212 is automatically fed into the filter container.
2. The dependent rim portions of the container 5 are lowered to seal the section of paper lying on the filtrate chamber.
3. The differential pressure controller 404 establishes a preset pressure differential between the chamber sealing space 402 and the filtrate chamber 403.
4. With the container 1 vented, approx. 15 l/m² of the suspension are introduced to the top container 5 and distributed over the surface of the sealed section of filter paper.
5. Compressed gas is introduced to the top chamber through control valve 407, whereby the gas pressure and flow controllers 405/6 control and indirectly establish the filtration characteristics of the suspension by measuring the volumetric flow of gas in the top container 5. A sample of filtrate flows through a turbidity meter 410 to record the degree of clarity of the filtrate.

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The computer 15 chooses the filtration mode and type of medium:

Mode: precoat with medium speed diatomite with 1% body-feed
Medium: 20 micron polyestermonofil section of belt

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6. The depending rim portions (3) are raised and the filter paper is discharged.
7. The 20 micron belt section is automatically positioned in the container 1.
8. Steps 3,4,5 are repeated with a liquid of known filtration characteristics.

9a. Result of permeability test: negative. The section of belt is subjected to a standard cleaning/regeneration procedure after which steps 3,4,5 are repeated.

9b. Result: positive. With the container 1 vented, approx. 20l/m² of diatomite suspension are introduced to the top container 5.

10. While the chamber 5 is being pressurized with gas, suspension to be filtered with 1% diatomite body-feed is introduced under pressure through valve 407. The feed rate is controlled by a pressure differential controller 405. Filtration proceeds.
11. On reaching a preset pressure differential, filtration terminates. Valve 401 shuts.
12. Valve 407 opens. Gas forces rest suspension through the filter cake.
13. Gas flow controller 406 signals a break-through of gas through the filter cake.
14. Valve 407 shuts.
15. The valve 408 opens. A pre-set quantity of wash liquid is fed to the container 5.
16. Valve 408 shuts. Valve 407 opens. Gas forces wash liquid through the cake.

17. The flow controller 406 signals a break-through of gas through the filter cake.

18. Cake drying.
19. The valve 407 shuts. Container is vented by opening 411. Container opens.
20. Belt transport. Cake discharge.
21. Belt wash (belt wash liquid is used for subsequent cake wash operation).
22 20 micron belt section relocated in the container 1.

-cycle repeated-

Fig.5 & 6 show a schematic representation of an innovative filtrate chamber 2 whereby the the fixed pervious bed of the prior art is replaced by manually removable pervious elements 502 to facilitate the cleaning and/or sterilization of the internal surfaces and drainage members 504. According to the invention only planar, smooth surfaces of the floor of the filtrate chamber remain after the manual removal of the elements. In a preferred design, the filtrate chamber consists of a hollowed-out plate 505 with smooth polished upper surfaces on which the removable elements, preferably consisting of expanded sheets or layers of woven mesh of metal or plastics that are covered and integral with flat perforated sheet, mesh or profiled grid material. To accommodate the high liquid through-puts of the invention and to minimize the bulk and cost of the elements, generously proportioned multiple filtrate outlet conduits 506 are provided, preferably coinciding with the intevals of the fluid driven cylinders 215, whereby the conduits are made integral with the supporting framework and designed to support the filtrate chamber as well as to withstand the thrust of the closure of the upper container. These conduits are also designed for ease of access and cleaning.
Fig.7 shows a schematic drawing, wherein the filter web takes the form of a belt that is driven by a motor or actuator 702 to reverse the direction of transport of the belt to enable the discharge of the filter bed or filter cake at either end of the purifying apparatus 1. One of the major advantages of this configuration is that the permanent attachment of a bed regenerator 6 and a filter cake receiver at either end can be achieved.

The above described invention effectively bridges the gap between prior art sand (in-depth) and pressure filters presently employed in the liquid processing industries.
The implications are that both liquid processing and using industries can be rationalized and improved to increase their competitiveness and simultaneously reduce considerably the present negative impact on the environment.